Estimation of Oxygen Dose by Spectroscopic Ellipsometry and Investigation of Oxide Formation Mechanism by FT-IR for $^{16}O^+$-Implanted Si Wafers

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INTRODUCTION

We investigated the formation of complex Si and GaN semiconductor substrates based on SOI (Silicon-on-Insulator) technology in order to realize monolithic electron-photon-merged devices [1]. In this case, a 3C-SiC layer is used as a buffer layer for the GaN epitaxial growth. The 3C-SiC layer is formed by carbonizing the top Si(111) layer of a SOI wafer. Although SIMOX(100) wafers with Si(100) on top are commercially available [2], SIMOX(111) wafers with Si(111) are not available because there are no uses for them in CMOS applications.

Through the investigation of the SIMOX(111) wafer formation, it has been found that doses of the oxygen-ion ($^{16}O^+$) implanted in Si(111) wafers can be estimated by spectroscopic ellipsometry, and their oxide formation mechanism can be also analyzed by Fourier-transform infrared absorption spectroscopy (FT-IR).

EXPERIMENTAL

Oxygen ions were implanted into FZ-Si(111) wafers at 180 keV with doses of 3, 4, 5, 6, 7, and $10x10^{17}/cm^2$. The wafers were kept at about 550 °C during the implantation. The spectroscopic ellipsometry and the FT-IR measurements were employed to characterize optical properties and the bonding structure of implanted oxygen atoms of the samples, respectively.

RESULTS AND DISCUSSION

Figure 1 shows the amplitude ratio angle Ψ-wavelength spectra of implanted samples and a non-implanted sample obtained by spectroscopic ellipsometry. While the spectrum of the non-implanted sample has no wave form, all the $^{16}O^+$-implanted samples clearly show the gradually enlarging wave forms in their spectra. The result implies that there is a strong correlation between the oxygen doses and the wave forms in the spectra. The maximum or minimum slopes on both sides of a valley in the spectra were calculated to quantitatively investigate the correlation. The investigation resulted in inducing an equation expressed by the Fermi-Dirac distribution function that clearly shows the relationship between the oxygen doses and the slopes. This means that the oxygen dose in Si can be estimated non-destructively by spectroscopic ellipsometry.

Figure 2 shows FT-IR spectra of as-implanted Si wafers with different oxygen doses. The peaks at 515 and 440 cm^{-1} in the spectra are well known to indicate the existence of oxygen in Si and in low-temperature CVD SiO_2 [3], respectively. As the oxygen dose increases, the peak height at 515 cm^{-1} decreases, while the peak height at 440 cm^{-1} increases. The results indicate the existence of interstitial oxygen atoms in low-dose samples and weakly-bonded oxygen precipitates. Increases in the oxygen dose result in increased oxygen precipitate, while decreasing the interstitial oxygen atoms. The large peak at 1100 cm^{-1} of the sample with a dose of $3x10^{17}/cm^2$ in Figure 2 can be separated into three peaks, as shown in Figure 3. The peaks at 1106, 1065, and 1010 cm^{-1} show the existence of oxygen in Si, oxygen in SiO_2, and the unbonded oxygen in Si [4], respectively. This spectrum analysis method drawn from FT-IR is effective in explaining the oxide formation mechanism in as-implanted Si.

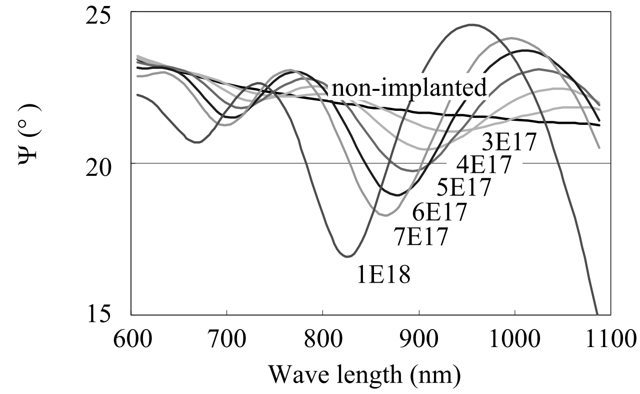

Figure 1. Amplitude ratio angle Ψ-wavelength spectra with different oxygen doses.

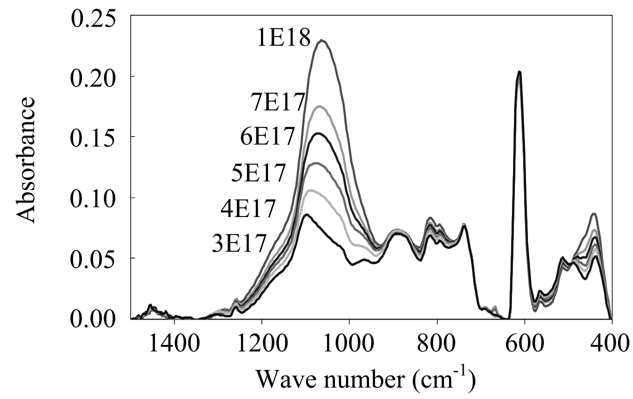

Figure 2. FT-IR spectra of as-implanted Si wafers with different oxygen doses.

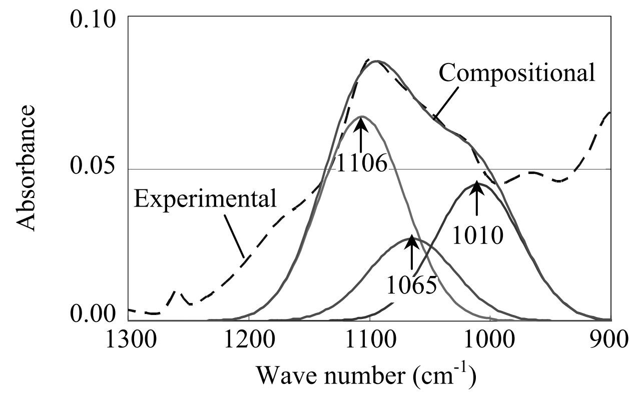

Figure 3. Separation of FT-IR spectrum.

SUMMARY

It has been revealed that the oxygen doses in the as-implanted Si(111) wafers can be estimated by spectroscopic ellipsometry, and their oxide formation mechanism can be also analyzed simply and non-destructively by FT-IR.

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